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Study on affecting factors and standard of rural household energy consumption in China

Wang Xiaohua *, Feng Zhenmin

College of Engineering, Nanjing Agricultural University, Nanjing, Puzhen 210031, PR China

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Abstract

In order to understand the basic character and development tendency of China's rural household energy consumption, we present the total rural household energy consumption of 1998 in China, which was 340.97 million tce (tons of standard coal equivalent, 1 tce $= 7 \times 10^6$ kcal), according to statistics gathered from 30 provinces and 40.14% of which was commercial energy. This paper shows the correlation coefficients of the data, such as per-capita energy consumption of standard coal equivalent (PCEC), effective heat consumption for livelihood per capita per day (EHC), the proportion of commercial energy in EHC (PCE), annual electricity consumption for livelihood per capita (AEC) and so on. The paper suggests using EHC, PCE and AEC as the character indices to further reveal the correlation of per-capita income (PCI) and average annual temperature (AAT).

Keywords: Energy planning; Biomass; Energy utilization; Fuels; Rural areas

Contents

* Corresponding author. Tel./fax: +86-25-86-06671.
E-mail address: wangxh@jlonline.com (W. Xiaohua).

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1. Introduction

The household energy consumption in rural area composes an important part of China's national energy consumption [1]. The household energy consumption is determined both by the demand and supply in the energy market; the supply includes commercial energy obtained from the market and biomass energy from the local natural resources. China has made several achievements in the research of rural household energy consumption. A nationwide survey shows that the rural household energy consumption, of which 70% is biomass energy, accounts for 40% of the country's total energy consumption in 1979 [2,3]. The shortage and inefficient use of energy in rural area has troubled China for a long time. At the same time, differences in consumption level and structure exist among regions, which are determined by the amount of natural resources locally available. The household energy consumption each year amounts to 700–1200 kgce, 40–60% of which is used for cooking. Sixty to 90% of energy consumption for cooking is supplied by biomass energy. The straw stove's thermal efficiency runs between 10% and 20% [4]. A five-year successive study in Yangzhong, Jiangsu province indicates that the varieties of energy in household consumption are changing quite a lot during the replacement of non-commercial energy by commercial energy. The consumption of electric power and LPG are rising, while that of straw and coal is declining. The energy consumption per capita remains relatively stable, and effective heat use has increased slightly. There is certain correlation between energy consumption per capita and income per capita, average number of persons per household and crop yield per capita [5–13].

Based on the statistics of rural household energy consumption from 30 provinces in China in 1998 [14], this article has analyzed the rural household energy consumption standard and composition and studied the correlation between the character index and affecting factors. It provides a reference for the people researching the development tendency of rural household energy consumption, which is very important to the national energy development scheme and the market balance of demand and supply.

2. Figures and approaches

Rural household energy consumption was used for cooking, water heating, feeding, lighting and electric appliances, and the remainder. There could be any number of indices that reflect the characteristics of rural household energy consumption. We select per-capita energy consumption of standard coal equivalent (PCEC, PCEC is the sum of various kinds of energies in standard coal equivalent), effective heat consumption for livelihood per capita per day (EHC, EHC is the sum of various effective heat energy used for cooking, heating and boiling pig food), the proportion of commercial energy in EHC (PCE) and annual electricity consumption for livelihood per capita (AEC), per-capita commercial energy consumption (PCCEC, PCCEC is the sum of various commercial energies in standard coal; electricity is calculated by 1 kW h = 0.404 kgce), and per-capita straw possession (PCSP, PCSP is the quantity of straw and stalks that each person occupies), etc. as major indices. The thermal efficiency of stoves using straw and firewood is 19%, coal 25%, LPG and biogas 60%.

The statistical figures from the *Yearbook of China's Rural Household Energy Consumption* [14] are used (Tibet is not listed, and abnormal figures have been rectified) and the software package of social science (SPSS) is adopted in analyzing and processing figures as to ensure the reliability and accuracy of the conclusion.

3. Rural household energy consumption standard and composition

The calculation shows that the total rural household energy consumption in China in 1998 was 340.970 million tce, of which 136.860 million tce was commercial energy. The consumption of commercial energy accounts for 12.68% of the total consumption of the whole country. The straw and stalks, firewood, coal, electric energy, fuel oil, biogas and LPG are 35.2%, 24.4%, 29.6%, 8.5%, 1.4%, 0.3% and 0.4%, respectively, of the total rural household energy consumption (Fig. 1). PCEC is 361.8 kgce, EHC 74.99 kgce, ACE 69.58 kW h, PCCEC 143.45 kgce, PCE 44%. Table 1 shows the indices and major affecting factors of rural household energy consumption in provinces of the country.

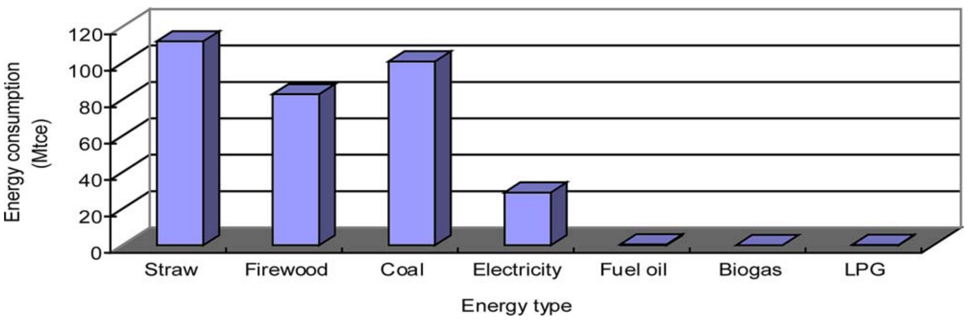


Fig. 1. Rural household energy consumption by energy types in China in 1998.

Table 1
Appraisal index and major affecting factors of rural household energy consumption in China in 1998

Provinces	PCEC (kgce)	EHC (kgce)	AEC (kW h)	PCCEC (kgce)	PCE (%)	PCSP (t)	PCI (yuan)	AAT (°C)
Beijing	603.77	142.35	115.43	367.85	66	1.30	3223.65	11.00
Tianjin	570.35	127.36	93.48	307.75	60	0.84	2406.38	12.00
Hebei	438.40	91.18	71.60	236.94	58	0.84	1668.73	8.50
Shanxi	262.84	60.61	51.36	178.97	74	0.89	1208.30	8.50
Inner Mongolia	483.93	98.65	22.54	149.05	36	1.12	1208.38	4.50
Liaoning	525.08	107.74	103.53	201.15	42	0.93	1756.50	7.00
Jilin	543.52	110.88	107.97	201.19	41	2.28	1609.60	2.00
Heilongjiang	668.99	126.91	102.50	147.46	22	2.11	1766.27	−1.00
Shanghai	228.95	59.07	118.83	160.98	77	0.42	4245.61	15.50
Jiangsu	185.76	35.05	80.21	75.05	39	0.64	2456.86	14.50
Zhejiang	294.78	56.36	91.51	93.94	32	0.31	2966.19	17.00
Anhui	330.06	64.47	67.02	84.52	27	0.62	1302.82	15.50
Fujian	346.19	64.50	59.23	61.52	16	0.27	2048.59	18.50
Jiangxi	489.01	96.82	55.83	102.39	23	0.43	1537.36	18.00
Shandong	352.50	68.83	83.71	123.65	36	1.01	1715.09	12.75
Henan	248.70	50.78	47.18	97.95	43	0.74	1231.97	14.00
Hubei	374.19	76.05	65.75	127.28	37	0.65	1511.22	15.50
Hunan	244.47	47.94	63.35	101.25	41	0.40	1425.16	17.25
Guangdong	181.11	34.45	70.37	60.86	33	0.26	2699.24	22.50
Guangxi	292.59	55.90	66.64	66.03	22	0.41	1446.14	20.00
Hainan	347.16	69.09	86.39	99.93	32	0.33	1519.71	21.00
Chongqing	427.94	82.32	72.34	81.60	19	0.43	1158.29	9.50
Sichuan	280.24	55.15	80.79	111.23	39	0.50	1158.29	9.00
Guizhou	273.03	59.81	20.70	120.19	51	0.40	1086.62	15.00
Yunnan	425.49	86.66	56.65	136.88	36	0.48	1010.97	14.00
Shaanxi	322.58	65.10	81.47	166.63	54	0.51	962.89	9.50
Gansu	353.51	74.04	28.37	154.04	49	0.17	880.34	7.00
Qinghai	150.00	35.45	31.81	126.11	87	1.17	1029.77	1.50
Ningxia	227.81	49.36	40.11	135.54	64	2.22	998.75	7.50
Xinjiang	432.06	96.74	30.73	219.54	58	1.65	1136.45	5.00
Whole country	361.80	74.99	69.58	143.45	44	0.81	1577.74	–

4. Correlation between character indices and affecting factors of rural household energy consumption

4.1. Analysis of character index of rural household energy consumption

In order to analyze the correlation between China's rural household energy consumption and its affecting factors, we should first select the index that can reflect the main symptom of rural household energy consumption. Table 2 shows the *Pearson* correlation matrix according to the figures in Table 1.

The figures show that the EHC is obviously related with AEC and PCCEC, and the coefficients significant at 0.01 level are 0.978 and 0.744, respectively. There is

Table 2
Pearson correlation matrix

		EHC	PCE	AEC	PCEC	PCCEC	PCSP	PCI	AAT
EHC	Pearson correlation	1.000	−0.045	0.405*	0.978**	0.744**	0.435*	0.001	−0.436*
	Sig.(2-tailed)	–	0.812	0.026	0.000	0.000	0.016	0.995	0.016
PCE	Pearson correlation		1.000	−0.047	−0.225	0.565**	0.268	0.125	−0.376
	Sig.(2-tailed)		–	0.806	0.232	0.001	0.152	0.510	0.041
AEC	Pearson correlation			1.000	0.390*	0.372*	0.114	0.689**	0.066
	Sig.(2-tailed)			–	0.033	0.043	0.550	0.000	0.727
PCEC	Pearson correlation				1.000	0.606**	0.416*	0.040	−0.403*
	Sig.(2-tailed)				–	0.000	0.022	0.834	0.027
PCCEC	Pearson correlation					1.000	0.429*	0.228	−0.447*
	Sig.(2-tailed)					–	0.018	0.226	0.013
PCSP	Pearson correlation						1.000	−0.116	−0.729**
	Sig.(2-tailed)						–	0.542	0.000
PCI	Pearson correlation							1.000	0.326
	Sig.(2-tailed)							–	0.079
AAT	Pearson correlation								1.000
	Sig.(2-tailed)								–

* Correlation is significant at the 0.05 level (two-tailed).
** Correlation is significant at the 0.01 level (two-tailed).

Table 3
Rural household energy consumption character indices

Character indices	Definition	Unit	Average of whole country (1998)	Peculiarity reflecting household energy consumption	Change tendency with economic development
EHC	Per-capita useful heat consumption for cooking and heating	kgce	74.99	Amount	Stabile basically, increase slowly
PCE	Ratio of effective heat produced for cooking and heating by PCCEC to EHC	%	44	Quality	Increase rapidly
AEC	Annual per-capita electricity consumption for livelihood	kW h	69.58	Amount and quality	Increase rapidly

no obvious correlation between AEC and other energy consumption index. The AEC has a strong correlation not only with EHC, but also with PCCEC, and the correlation is 0.606. The PCCEC is obviously correlated with EHC, PCE and AEC and the correlation coefficient between PCCEC and PCE is 0.565.

There are no obvious correlations between EHC, PCE and AEC. They are relatively independent, reflecting various characters of the rural family life (Table 3). Therefore, they are suitable to be selected as the symptom indices for China's rural household energy consumption.

As an index reflecting the household demand for efficient energy, EHC represents the consumption standards in cooking, hot water supplying, livestock raising and heating in winter, excluding the energy consumption in heating by air-conditioner which is counted into AEC. PCE shows the improvement of living conditions and crucial change in energy consumption. The household electric power consumption comes mainly from well-off families in using TVs, washing machines and electric fans, etc. AEC is an important index reflecting people's living standard and quality.

4.2. Correlation between consumption character index and per-capita income and average annual temperature in different areas

The main affecting factors of rural household energy consumption are per-capita income (PCI) and average annual temperature (AAT) in different areas. Figs. 2–4 are the scatter plots of EHC vs. AAT, EHC vs. PCI and AEC vs. PCI, respectively.

The analysis of consumption character index and affecting factors shows that the EHC has moderately strong negative correlation with AAT, and the correlation coefficient is −0.419 and the non-correlation probability is 2.1% (Table 2). This shows that if the AAT decreases, EHC increases and vice versa—not perfectly so, but there was a strong tendency for this to happen.

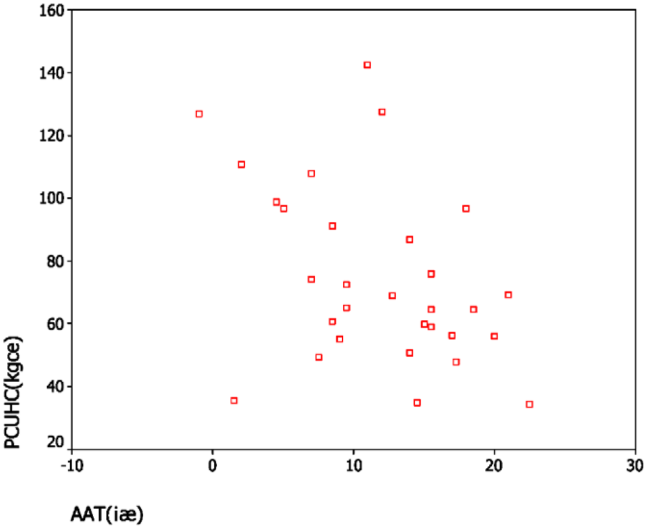


Fig. 2. The scatter plot of EHC vs. AAT.

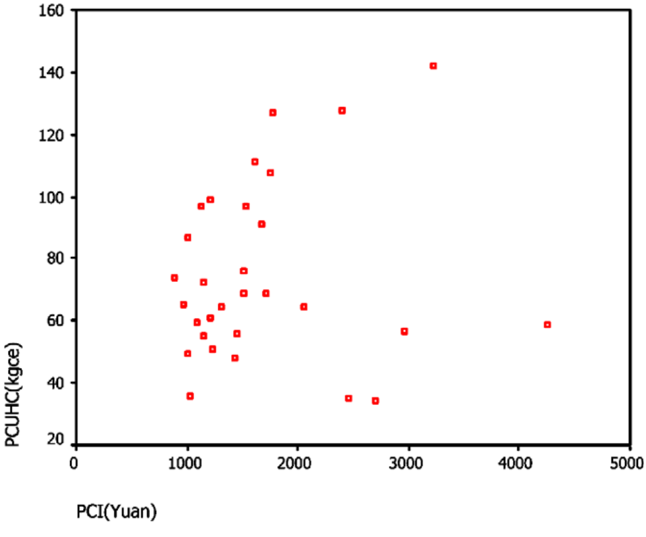


Fig. 3. The scatter plot of EHC vs. PCI.

There is a moderately strong positive correlation between EHC and PCI for the provinces having PCI less than 2000 yuan RMB at provincial level. The data on county-level indicated that there is a moderately strong positive correlation between EHC and PCI [4]. The analysis shows that the correlation coefficient

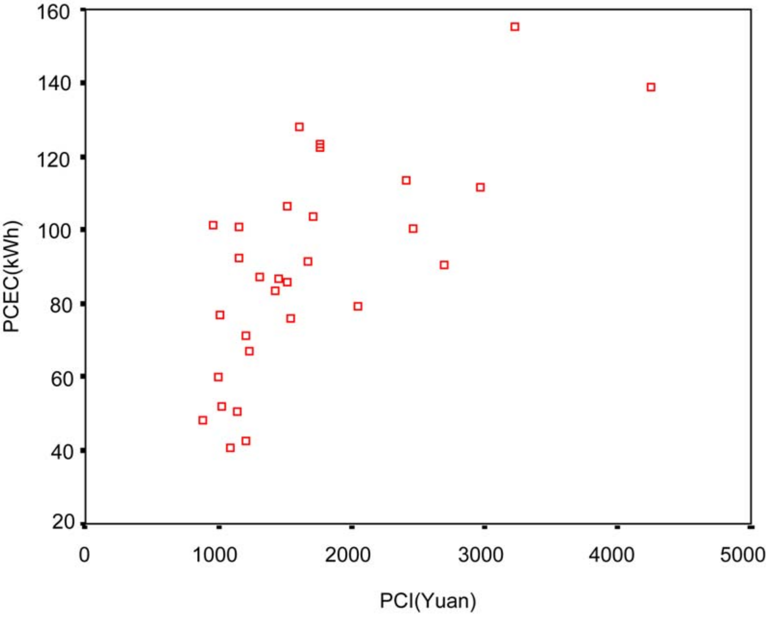


Fig. 4. The scatter plot of AEC vs. PCI.

between EHC and PCI is 0.522 and the non-correlation probability less than 0.01%; through regression analysis, suppose the correlation between EHC (kgce) and PCI (yuan RMB) is as $\text{EHC} = a + b\text{PCI}$, we get the regression equation as:

$$\text{EHC} = 16.60 + 0.04413\text{PCI} \quad (1)$$

Through calculation, correlation coefficient $r = 0.522$, sample size $n = 23$; when obviousness level $\alpha = 0.05$, the critical value of correlation coefficient $r_{0.05} = 0.361$. Since $|r| > r_{0.05}$, there is a strong correlation between EHC and PCI. The residuals statistics in Table 4 shows that the fitted model is adequate and appropriate.

There exists a strong correlation between AEC and PCI. Correlation coefficient is 0.689 and non-correlation probability less than 0.01%; through regression analysis, suppose the correlation between AEC (kW h) and PCI (yuan RMB) is as

Table 4
Residuals statistics (dependent variable: EHC)

	Minimum	Maximum	Mean	Standard deviation	N
Predicted value	55.4600	94.5566	74.9942	12.1917	23
Residual	−31.5641	32.3496	1.081×10^{-14}	19.9052	23
Standard predicted value	−1.587	1.620	0.000	1.000	23
Standard residual	−1.549	1.588	0.000	0.977	23

Table 5
Residuals statistics (dependent variable: AEC)

	Minimum	Maximum	Mean	Standard deviation	N
Predicted value	49.3197	134.6674	69.5800	19.7614	30
Residual	−35.0944	40.1581	-2.1198×10^{-14}	20.7985	30
Standard predicted value	−1.025	3.294	0.000	1.000	30
Standard residual	−1.658	1.897	0.000	0.983	30

$\text{AEC} = a + b\text{PCI}$, we get the regression equation as:

$$\text{AEC} = 26.993 + 0.02536\text{PCI} \tag{2}$$

Through calculation, correlation coefficient $r = 0.689$, sample size $n = 30$; when obviousness level $\alpha = 0.05$, the critical value of correlation coefficient $r_{0.05} = 0.463$. Since $|r| > r_{0.05}$, so there is a strong correlation between AEC and PCI. The residuals statistics in Table 5 shows that the fitted model is adequate and appropriate.

There is no significant correlation between PCE and PCI.

5. Conclusion

The total rural household energy consumption in China in 1998 is 340.97 million tce. The consumption of commercial energy accounts for 12.68% of the total commercial consumption of the whole country. The straw and stalks, firewood, coal, electric energy consumption were 35.2%, 24.4%, 29.6% and 8.5%, respectively. PCEC is 361.8 kgce, EHC 74.99 kgce, AEC 69.58 kW h.

The analysis shows the EHC, PCE and AEC have no obvious correlation with each other, which can be selected as basic character indices for rural household energy consumption. The EHC has not only a strong correlation with AAT, but also a strong positive correlation with PCI for the provinces having PCI less than 2000 yuan. The regression equation is $\text{EHC} = 16.60 + 0.04413\text{PCI}$. The AEC is obviously correlated with PCI, the regression equation of AEC and PCI is $\text{AEC} = 26.993 + 0.02536\text{PCI}$. There is no correlation between PCE and PCI.

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